A 45,000-yr Rodent Midden Record from the Margin of Absolute Desert in the Central Atacama of Northern Chile (22-24°S)

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Paleoclimatic research in the central Andes has accelerated in recent years with the need to better resolve leads and lags by high versus low latitude climate forcing. High Andean lake records from the Altiplano of Bolivia (*1*, *2*) and Chile (*3*) are in conflict regarding the timing and extent of past pluvial phases, which in turn have been used to infer past intensity of the South American Summer Monsoon (SASM). Dating control is problematic in some of these records, however, and effects between temperature and precipitation are difficult to distinguish.

These shortcomings can be surpassed in reconstructing a vegetation history for the adjacent hyperarid Atacama Desert, where the scarce rainfall that occurs is the result of tropical summer storms that spill over from the Altiplano. Plants on the margin of the Absolute Desert (a hyperarid core that completely lacks terrestrial plants) are very sensitive to seasonal precipitation changes with only secondary temperature effects.

Here we present data from two rodent midden records obtained in the central Atacama Desert (22-24°S) of northern Chile. Middens are amalgamations of plant remains, rodent feces, insects and vertebrates encased in hardened urine that, in the Atacama, are produced mostly by *Lagidium viscacia* (Chinchillidae) and *Phyllotis* spp. (Muridae).

The first record includes 46 ^{14}C-dated fossil rodent middens sites from the upper margin (2400-3100 m) of the Absolute Desert. Plant macrofossils, percent grass, and plant cuticle analyses from these middens record past plant invasions onto lifeless landscapes for the last 45 cal kyr BP (Fig. 1).

Few middens and low species richness indicate dry, and possibly cooler, conditions between 40.1-22 cal kyr BP in the lower altitude record (Fig. 1). Lowering of steppe grasses by up to 1000 m, prominence of C_4 grasses/summer annuals, high species richness, and displacement of northern species by at least 50 km south of their modern ranges indicate a large increase in summer rainfall between 16.2-10.5 cal kyr BP. Precipitation increase was greatest for a cluster of middens between 11.8-10.5 cal kyr BP. Abrupt drying, evident in a dramatic decrease in grass abundance, happened after 11.7, between 11.9-10.2, 11.2-10.9, after 10.5, and between 10.7-9.5 cal kyr BP at five different midden localities. Increased percentages of grass, higher species richness and extralocal taxa may record slightly wetter conditions between 7.1-3.5 cal kyr BP. Present hyperarid conditions were established after 3 cal kyr BP.

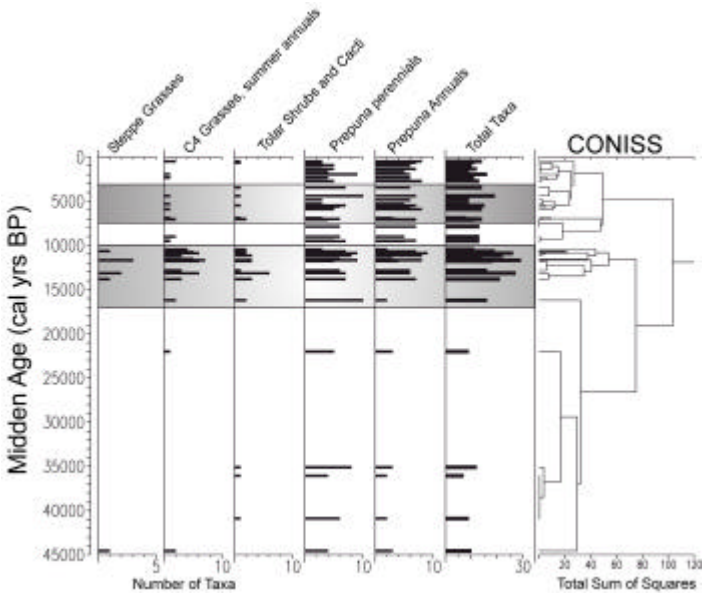

Figure 1. *The number of taxa ordered by lifeform and phytogeographic category obtained from 44 fossil rodent middens from localities within the Absolute Desert. Well-defined clusters of middens indicate times of increased precipitation in the central Atacama (shaded zones).*

The second record includes 28 ^{14}C-dated middens collected between 3100-3250 m, well

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into the transitional, shrub-dominated vegetation belts known as the Prepuna and Tolar. Grass

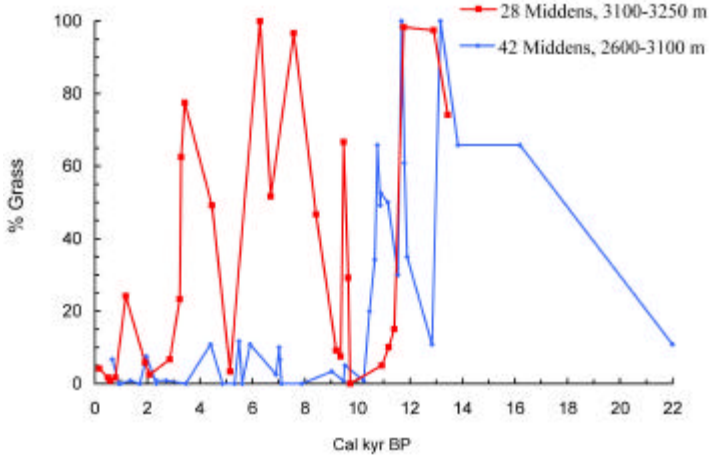

Figure 2. *Grass percentages from both midden records indicate increased precipitation during the late Pleistocene and during the middle Holocene.*

percentages obtained from these middens (Fig. 2) are therefore more sensitive to smaller increases in precipitation that might go undetected in the lower altitude middens.

Grass percentages from this record indicate increased summer rainfall at 13.4-11.8 cal kyr BP and again between 8.4-3.3 cal kyr BP as grasses rise to >50% (punctuated by a sharp drop at 5.2 cal kyr BP). Abrupt drying, indicated by low percentages, occurred after 11.4 to 9.7 cal kyr BP. and after 3.3 cal kyr BP, when save for a brief increase to 24% at 1.2 cal kyr BP, these remain <10% (Fig. 2). Thus, slight increases in precipitation during the mid-Holocene as evinced by lower elevation midden macrofloras are further corroborated by significantly increased grass percentages in the higher altitude midden record.

Increased precipitation during the mid Holocene in the central Andes is hotly debated, as both archaeological and geological records from the central Atacama (*4*) and Lake Titicaca (*5*) have been interpreted as reflecting pronounced mid Holocene aridity. The higher elevation midden record shows a pronounced mid Holocene wet phase between 8.4-3.3 cal kyr BP, supported by increased C_4 grasses and Tolar shrubs in the lower elevation record and by higher groundwater levels in the central Atacama (*6*, *7*).

Direct forcing of the SASM by solar insolation over tropical South America is proposed to explain precipitation increases observed in records from Lago Junin in Perú (*8*), the Amazon fan (*9*) and at Salar de Uyuni, Bolivia (*1*). The central Atacama Desert is at the edge of SASM influence and present-day variability of summer precipitation is a measure of its intensity. Summer insolation was at its minimum over the central Andes (20°S) during the latest glacial-early Holocene transition so regional insolation forcing cannot account for an intensified SASM and pluvial conditions in the central Atacama. Because monsoonal circulation collapsed abruptly, between 11-10 cal kyr BP, either a nonlinear relationship with seasonal insolation or abrupt change in one or more key features of the SASM are possible. We suggest that the SASM was enhanced by remote forcing of intensified Walker Circulation (stronger easterlies) and La Niña-like conditions operating through insolation anomalies (*10*) directly over central Asia and the equatorial Pacific.

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